EVALUATION OF REMEDY ALTERNATIVES FOR THE MT. SIMON-HINCKLEY

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Introduction

This memorandum presents a summary evaluation of remedial action alternatives for the Mt. Simon-Hinckley aquifer (MSH). This memorandum evaluates 1) the likelihood that the MSH has been contaminated by activities at the former Reilly Tar & Chemical Corporation (RT&CC) plant, 2) the cost and feasibility of determining the extent of any contamination that may exist and what to do about such contamination, and 3) the feasibility, cost and reliability of alternative remedial actions that can be reasonably foreseen at this time if the MSH is indeed contaminated. The purpose of these evaluations is to provide background infomration on the action for the MSH embodied in the proposed Remedial Action Plan for the RT&CC site.

Extent of Contamination in the MSH

There is no direct evidence that the MSH has been contaminated by the activities at the RT&CC site. Regular monitoring of St. Louis Park (SLP) municipal wells in the MSH over the last five years has shown no evidence of PAH contamination. Despite considerable efforts, representative samples of the MSH could not be collected during the exploration and clean-out work at on-site wells W23 and @105 in 1982 and 1984, respectively. Hence, the presence and extent of PAH contamination in the MSH can be present only by hypothesized from indirect and circumstantial evidence.

The following discussion summarizes our best judgments on the likely presence and extent of contamination in the MSH. Two basic cases are considered: 1) contamination that may have occurred during the operating history of the RT&CC plant, and 2) contamination that may have occurred during exploration of W23 and W105.

Plant Operations As A Source

Contamination from plant activities could only have entered the MSH via W23 or W105, the only two on-site wells drilled to the MSH. Leakage of contaminants from upper aquifers through confining beds to the MSH is impossible in the time-frame of the plant's operation.

Table 1 summarizes the chronology of key events at wells W23 and W105 with respect to their possible roles as conduits for contamination reaching the MSH. All of the events listed are documented, except for the area 1930 estimate for the formation of a shale bridge in W23 in the Eau Claire at 740 feet. This date is inferred from the hypothesis that the plug of coal tar-like material in W23 accumulated over many years by 1) settling of "free-phase tar" from highly contaminated water leaking into the well from the Drift-

Platteville and/or 2) "dripping" of tar that coated the well bore and casing as a result of a possible earlier spill down the well.

Depth measurements at W23 indicate taht the top 55 feet of the plug accumulated from 1958 to 1978. If the resulting accumulation rate of 2 3/4 feet per year implied by these measurements is applied to teh bottom half of the plug, then a period of 29 years is implied to accumulate the 80 feet of coal tar-like material in the lower half of the plug. (From the shale bridge at 740 to the 650 foot depth measured in 1958, less 10 feet for the gravel poured in the well in 1958.) This would imply that the shale bridge was formed in about 1930. This is only a rough estimate, of course, and the shale bridge could have formed earlier. Exploration of W23 in 1982 found that the hole contained collapsed shale from 780 feet deep to the point where the bailer was lost (866 feet). This indicates that the Eau Claire shale could have collapsed soon after the hole was drilled, forming the shale bridge upon which coal tar-like material later accumulated. This also indicates that the interval of the well bore adjacent to the Mt. Simon may have been filled with shale for much of the life of the well, and this shale would restrict the movement of both water and contaminants to the Mt. Simon.

The two basic means by which contamination could have entered the MSH via wells W23 and/or W105 are 1) a spill or spills and 2) long-term leakage. Table 2 summarizes the likelihood of these two mechanisms as sources for each well, based on the events listed in Table 1 and reasonable conjecture as to liekly contaminant flow of mechanisms and behavior. The two key concepts underlying the judgments indicated in Table 2 are that 1) the coal tar-like plus in W23 was an effective barrier against contamination entering the MSH and 2) an appreciable period was required before the surficial aquifer in the immediate vicinity of W23 and W105 became highly contaminated. The first concept is based on the high resistance of coal tar to wear or penetration by water. The second is based on the judgment that the Drift-Platteville on-site was contaminated primarily by leaks and spills over the history of the plant's operation.

Table 2 indicates that the only MSH contamination mechanism judged to be other than "very unlikely" could only have existed prior to the early 1930's, and even these mechanisms are judged to be "unlikely" (odds of roughly 1 in 4). In this context, contamination of the MSH means PAH concentrations exceeding drinking water criteria more than a few feet from the wells. Subsequent evaluations of potential remedial investigation work and remedial actions in this means, therefore, are based on the assumption that contamination of the MSH may have occurred prior to 1930, but no further contamination source(s) existed after 1930. The only exception to this assumption is contamination that may have been introduced during the exploration of wells W23 and W105 in the early 1980's, which is considered below.

Well Exploration As A Source

In addition to possible contamination of the MSH during the RT&CC plant operation, concern has also been expressed over possible contamination introduced during exploration of W23 and W105. Well W23 was left open during August and September of 1982 after the bailer was lost at 866 feet. During this period, contaminated water in the well could have entered the MSH. However, there is every reason to believe that contaminant migration into the Mt. Simon during this period was very minor, if any occurred at all. The most compelling evidence that supports this is water level data collected during this time period. With the four-inch casing with a packer at 595 feet in place, water levels measured inside the four-inch casing were on the order of 40 to 60 feet below the ground surface. Water levels outside the four-inch casing (inside the ten-inch casing) were about 30 to 45 feet below the ground surface. These measurements clearly indicate that packers at the 250-foot depth and at the 595 feet were not forming a seal to prevent hydraulic connections between aquifers. Instead of representing water levels in only the formations that the packers were supposed to isolate, the measured water levels represented some sort of combined level for many hydraulically connected formations. It also appears, however, that the Mt. Simon formation was not appreciably involved in that connection, or in other words, the Mt. Simon was apparently hydraulically isolated from W23. This observation is based on water level measurements that were made starting in June 1982 when the work on W23 began. During the entire time the coal tar-like plug of material was being bailed from W23 up to and including the time that the interval from 840 to 866 feet was bailed (probable Mt. Simon Formation) the water levels remained essentially enchanged (varied only between 40 to 60 feet below surface and between 30 to 45 feet in four and ten-inch casings respectively).

Based on static water levels in SLP11, SLP12, and SLP13 and on figures in Norvitch, et al. (1973), the potentiometric surface in the Mt. Simon should be between 200 and 300 feet below the ground surface at W23. Water levels in all above-lying aquifers are about 100 feet or less below ground surface. Therefore, a hydraulic connection driven by a head difference of at least 100 feet should have produced a measurable change on the composite water levels being measured. Without any direct measurements or other evidence to the contrary, this strongly suggests that there was no significant down-hole flow in W23 which entered the Mt. Simon, thus any contamination of the MSH aquifer would be minor indeed.

It is difficult to estimate what sort of flow may have been possible from W23 into the Mt. Simon during August and September, 1982, because of the significant unknown factors affecting the flow. One such factor is the deposits of collapsed shale that continually plagued attempts to TV-log the bottom of W23 to view the lodged bailer. Analogous to these deposits blocking further penetration of the TV camera, the collapsed shale would greatly rrestrict any flow of water through the well bore. Other factors are entrance losses to the well, which would take place presumably over the distance in the wel from the point of entry (which is unknown due to leaky packers, but could be assumed to be at the Ironton-Galesville) to the measured water level inside the four-inch casing. There would also be friction losses along the well bore tending to reduce the total down-hole flow. A final piece of evidence which supports the conclusion that the Mt. Simon was effectively isolated from W23 during the period in question is teh result of a pump test on September 17, 1982, when a pump was lowered to 812 feet with a packer at about 785 feet below ground surface. Although the pump only delivered about 3 to 4 gpm the well was pumped dry within about five hours. This indicated that the packer was effective in preventing water from above from getting into the pump, and most importantly indicated that water was not entering W23 from the Mt. Simon, i.e., there was no hydraulic connection and no means by which water could flow from the well into the aquifer.

The results of the September 17, 1982, pump test indicate that 1 gpm is a reasonable estimate of the maximum downhole flow entering the MSH during the two months that W23 was open to the MSH. This is based on the flow from the MSH into a dry hole under 600-700 feet of head being less than 3 to 4 gpm, compared to a maximum head of about 200 feet available for downhold flow. If one assumes that this water contained 1 ppm total PAH, then 1 gpm for two months would have introduced about 0.7 lb. total PAH to the MSH. This contamination would take about 70 to 110 years to reach SLP11, assuming no retardation by adsorption (see next section), but significant retardation is expected in the MSH for all but the lowest molecular weight (<u>i.e.</u>, two-ring) PAH. One can conservatively assume a difference in the travel times between the "front" and "back ends" of the plume (<u>i.e.</u>, low and high molecular weight PAH) of a factor of 3, due to retardation by adsorption. This is very conservative, since it is probably more like a factor of 30. The factor of 3 for retardation results in a 50 to 70 year time lag between the front and back ends of the plume. Diluting 0.7 lb. of PAH in 300 million gallons per year of pumping (approximate rate at SLP11) over 50 to 70 years yields an average concentration of 4 to 6 ng/l, which would not be detectable relative to background or blank concentrations. This is a worst-case estimate, with 1 ng/l being a much more reasonable estimate given expected retardation effects and some irreversible adsorption. Hence, we conclude that the exploration activities at W23 are very unlikely to have introduced sufficient contamination to ever measurably affect a MSH drinking water supply well.

[I need help on how to handle W105.]

Migration of Any Contamination

Modeling of groundwater flow in the MSH by ERT and others indicates that groundwater flow directions and velocities are very strongly influenced by pumpage at MSH drinking water supply wells. In the general vicinity of W23, groundwater flow towards Well SLP11. However, this well was installed in 1961, while we believe that the most likely source(s) of MSH contamination stopped after about 1930. Hence, one must consider two groundwater flow regimes--pre- and post-1961--in evaluating the likely migration of any MSH contaminants.

Post-1961 groundwater flow in the MSH is best illustrated by stream-line flow modeling performed by ERT. Figures 1 and 2 show groundwater flow stream-lines under two sets of modeling conditions. The differences between the two runs are in the pumping rates used for SLP MSH wells, the transmissivity used and the hydraulic conductivity used (see Table 1). The Run 1 reflects flow pumpage at SLP12 and 13 and high pumpage at SLP17, while Run 2 inverts this pattern. The Run 2 uses a slightly higher transmissivity that appears to be based on an SLP11 pump test. The different hydraulic conductivity values are discussed below.

I tis important to note that the travel path in ERT's stream-line modeling is only a function of transmissibity, graident, pumping rates, and gradient direction (assumed due east). The hydraulic travel time is a function of the resulting head contours, plus hydraulic conductivity (K) and porosity. The value of K of 6.5 ft./day used in Run 2 to estimate hydraulic travel time is conservative. As shown in Table 2, other reasonable estimates give lower values of K, with resulting travel times of well over 100 years. The Run 2 conductivity of 8.2 ft./day is probably unrealistically high. Hence, an analysis is based on a K of 6.5 ft./day, yielding a hydraulic travel time of 72 to 107 years (Table 2) is conservative.

Since any contamination of W23 has been traveling to SLP11 since it was drilled 24 years ago, this leaves 48 to 83 years of hydraulic travel time, or 58 to 100 years if 20 percent is added for retardation.

It should be noted that use of a 1.2 retardation factor is very conservative. While this is a reasonable estimate of the retardation factor for naphthalene in the MSH (based on tests by Cohen (1982) of St. Peter and drift samples), PAH absorption is a strong function of molecular size and shape. For the three-ring and four-ring compounds that are the predominant contaminants in Prairie du Chien-Jordan wells (acenaphthene, acenaphthylene, flourene, phenanthrene, pyrene, fluoranthene), retardation factors of 2 to 10 are more likely (see ERT App. E, Section E2.7 as revised per 11/27/84 errata list). Hence, the minimum contaminant transport time from W23 to SLP11 is more like a century or more.

Likely contaminant migration in the MSH prior to 1961 is more difficult to estimate from available information. Schoenberg (1984) indicates that the natural gradient in the MSH is towards the southeast, but there are few data available for estimating natural gradients. The current regional gradient of about 25 ft/mile is a reasonable ripper bound estimate of the pre-1961 gradient, with one-fifth this value as a reasonable lower bound. These gradients yield an estimated groundwater velocity before 1961 of 10-50 ft/year (based on K = 6.5 ft/day and n = 22%). We believe it is very unlikely that a contamination source(s) existed at W23 and/or W105 earlier than about 1920 or later than about 1930. This yields 30 to 40 years of available transport time under natural gradients prior to pumpage of SLP11, for a maximum possible contaminant migration distance of 250 feet to 1700 feet (based on a retardation factor of 1.2).

The probable result of these two groundwater flow regimes is that the most mobile (lowest molecular weight) of any PAH contaminants introduced at W105 or W23 prior to about 1930 are expected to have migrated to the southeast by 300 to 1700 feet until 1961, when they were then pulled back to the northeast by pumping at SLP11. The resulting areas of potential contamination in the MSH are shown in Figures 1 and 2. Note that in Run 2, some of the most mobile contamination is shown to be outside of the SLP11 capture area, although this is only the case for high natural gradients prior to 1961. Also note that the inferred contamination areas shown would not exhibit uniform concentrations or molecular weight profiles. Due to absorption effects, higher molecular weight and carcinogenic PAH would be expected in a smaller, roughly triangular area near W23 or W105, grading to the lowest molecular weight out at the northeastern-most points of the contamination areas.

Remedial Investigations

The only way to know whether the MSH is contaminated and, if so, to what extent, is to drill a new monitoring well or wells, since the bottom halves of W23 and W105 have obstructions and have been filled with bentonite. The problem is that the great depth to the MSH (about 900 feet) poses serious cost and feasibility difficulties, as described below.

E. H. Renner & Sons has estimated a probable cost of $180,000 to drill a simple new MSH well, with a likely range of $150,000 to over $200,000. This cost is based on a 6-inch finished diameter well, which could be recompleted as a pumping well capable of 100 gpm. A 12-inch well capable of 500 gpm would be of comparable cost (more material but less labor compared to a 6-inch well). A 4-inch well could cost more, given the greater difficulty of working in a smaller hole at great depths. Renner estimates that 8 to 12 months would be required to drill a new MSH well. There is a chance that the cost and time could be much higher if difficulties are encountered with collapse of the St. Peter. Some sense of the potential difficulties that can be encountered is indicated by SLP's experience in drilling a new MSH well (SLP17) two years ago, which cost almost twice the original estimate of $400,000 and took 18 months to complete.

Given the large cost and long time required, careful thought would be required in locating a new MSH well(s). The problem is that samples from a single well location would provide limited information on teh areal extent lof contamination, while multiple wells would be required in series to make use of earlier results in selecting locations, resulting in multiple years of drilling and inconvenience for the residents in the site area. Moreover, a new well location should be selected based in part on possible later pumping of the well as a remedial action, not just on defining contamination areas, in order to minimize cost and time requirements.

Figure 3 shows a logic diagram for the problem of locating one or more new MSH monitoring wells. The only case where drilling, sampling and analyzing a single new well and finding it to be uncontaminated leaeds to the conclusion that no further action is required is for a well located near W23. Any other location or sampling result would require a decision between 1) pumping that new well to control further spread of contamination, based on revised inferences of the areal extent of contamination, and 2) drilling a new well to further define the presence/absence or areal extent of contamination. Taking the later route would require at least two, and possibly three or more new MSH wells, at a cost of $400,000 or more, plus two years kor more for drilling. Taking the former route would require designing a remedial action with very limited information, although this could be done, as described below.

Potential Remedies

MSH Pumping Options

If contamination is found in the MSH by monitoring a new MSH well, it is possible that the well could be pumped to remove the contamination, prevent its further spread, and/or prevent its travel to SLP11. Which of these objectives would be achieved depends on the location of the new well, the contaminant levels found, and the inferred extent of contamination. At a minimum, the new MSH well presumably would be pmpted to prevent SLP11 from becoming contaminated. The precise pumping rate and means for disposing of the discharge water are, of course, very speculative at this time. Nonetheless, some reasonable cases can be postulated to bracket the likely range of costs.

Figures 3 and 4 illustrate the inferred areal extent of contamination in the MSH compared with estimated capture areas for pumping of a new MSH well for two different cases of well locations. The first case (well X, capture area XX) involves a well located near W23 that would be pumpted at a high rate (400 gpm) to retract most of the inferred contaminant plume. The second case (well Y, capture area YY) involves a well located near the point of 24 year hydraulic travel from W23 to SLP11 that would be pumped at a lower rate (100 gpm) to capture the W23 "source" area and retract about half of the inferred contaminant plume.

The contamination zones and capture areas shown in Figures 3 and 4 are, of course, very approximate, and assume that the MSH is indeed contaminated. Nonetheless, they do illustrate the concepts of a new well located close to W23, which could have to be pumpted at a high rate if contamination is discovered, as opposed to a new well located down-gradient of W23, which could be pumped at a lower rate if contamination is discovered.

It is difficult to predict discharge quality for pumping a new MSH well given the lack of data on MSH contamination. Significant dilution by uncontaminated water in the case of pumping 400 gpm means that the discharge very likely could be sent to a storm sewer without treatment. It also seems likely that discharge from a 100 gpm well could also be discharged without treatment given its location downgradient of W23, although there is an outside chance that treatment or sanitary sewer discharge would be required.

MSH Pumping Costs

Based on the above discussions, costs for pumping a new MSH well were developed for three cases, 1) pump 100 gpm without treatment, 2) pump 100 gpm with treatment, and 3) pump 400 gpm without treatment. each case requires a pump and housing ($10K to $20K, depending on capacity), a storm sewer connection, and an NPDES permit application (estimated to cost $10K). Storm sewer installation was costed at $30/foot, with up to 500 feet required to tie a 100 gpm well to the 30-inch storm sewer along Library Lane (which goes to Bass Lake) and about 1200 feet to tie a 400 gpm well to the same 30-inch line (greater distance because closer to W23 - see Figures 3 and 4). Annual operating, maintenance and monitoring costs are estimated at $2,600/year for 2 hours/week labor, $2,000/year for quarterly PAH monitoring, 10% of capital costs for maintenance, and electrical charges (at 5 cents/kwhr) of $4,100/year at 100 gpm and $18,700/year at 400 gpm.

Treatment costs are very hard to estimate reliably. Our rough guesstimate is $75,000 to build a 100 gpm ozone treatment plant (for 1 to 2 mg/l ozone dose, 60 minute residence time), plus $10,000/year O&M (excluding monitoring).

Cost Comparisons

Table 3 summarizes capital, O&M and prevent value costs for the various actions and options discussed above. Present value costs are calculated for 2% and 5% annual interest rates. The 5% rate was used in ERT's April 1983 report and is a conservative estimate of long-term real interest rates (nominal rates less inflation rates) (see Pat Fleischauer's 12/5/84 testimony summary). The 2% rate was suggested by the MPCA during fall 1983 settlement negoitations, and is extremely conservative. All present value costs are based on 50 years of operation (GAC treatment or MSH pumpage).* For comparison, it is noteworthy that most EPA-sponsored feasibility studies us a 10% interest rate and a 30-year time period, which yield much lower costs.** Bases for the cost estimates are provided in the notes to Table 3.

Table 4 summarizes total present value costs for the three MSH pumping cases (100 gpm with and without treatment and 400 gpm with treatment), including drilling and monitoring a new MSH well, compared to the cost of GAC treatment at SL)11 some time in the future. The variation of GAC treatment PVC as afunction of the time that treatment is required is shown for contaminant travel times ranging from 50 to 100 years (see Table 2). GAC treatment costs are also shown for the two cases of 1) building a new plant, and 2) tying in to the SLP10/15 plant.

Table 4 shows that a 5% real interest rate, the PVC of any MSH pumping option greatly exceeds the PVC of later GAC treatment (less than $100,000 for GAC versus at least $400,000 for pumping). Even at a 2% real interest rate, the PVC of MSH pumping is greater than that of GAC treatment (with a single exception among the various case combinations). Our opinion of the most likely cases are underlined (GAC treatment in 80 years versus 100 gpm MSH pumpage without treatment). The difference if PVC for these cases is over $200,000 at a 2% interest rate and over $350,000 at a 5% interest rate.

Two other noteworthy points are indicated by Tables 3 and 4. First, at a 5% reeal interest rate, the PVC of future GAC treatment at SLP11 is at least twice as low as the cost of drilling and monitoring a new MSH well. Hence, it would be more cost-effective to simply monitor existing MSH wells and provide for the possible need to treat SLP11 in the distant future than to drill a new well to see if the MSH is contaminated, even if no subsequent action is taken. Second, if a single new MSH well is to be drilled for potential later use as a pumping well, it appears that it would be more cost-effective in the long-term to place it 1,000 to 1,500 feet downgradient of W23 (location Y in Figures 3 and 4) so that a lower pumping rate could be used to protect SLP11 if contamination is found.

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* 100 years of operation has little effect on O&M PVC at a 5% interest rate (a 9% increase), but does increase the O&M PVC at a 2% rate substantially (by 37%).

** The PVC conversion factors compare as follows:

PVC Basis	Future Cost to PVC	Annual Payments to PVC
10% for 30 years	0.0573	9.427
5% for 50 years	0.0872	18.256
2% for 50 years	0.3715	31.424